National Aeronautics and
Space Administration

**Headquarters**
Washington, DC 20546-0001

NASA

Reply to Attn of OI

AUG 31 1995

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, NW
Washington, DC 20554

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SEP 7 1995

FEDERAL COMMUNICATIONS COMMISSION



Dear Mr. Caton:

The National Aeronautics and Space Administration hereby submits comments to the proposed Rulemaking titled, "Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5-29.5 GHz Frequency Band, to Reallocate the 29.5-30 GHz Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and for fixed Satellite Services and Suite 12 Group Petition for Pioneer's Preference", CC Docket No. 92-297.

Sincerely,

Charles T. Force
Associate Administrator for
Space Communications

Enclosure

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SEP 7 1995

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

**In the Matter of**

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| **Rulemaking to Amend Parts 1, 2, 21 and 25 of the Commission's Rules to Redesignate the 27.5 - 29.5 GHz Frequency Band, to Reallocate the 29.5-30.0 GHz Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Services** | ) | **CC Docket No. 92-297** |
| **and** | ) | |
| **Suite 12 Group Petition for Pioneer's Preference** | ) | **PP-22** |

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COMMENTS OF THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Charles T. Force
Associate Administrator for
Space Communications
National Aeronautics and Space
Administration

August 28, 1995

The opportunity is at hand to provide American industry and the American public with the full range of benefits that both LMDS and satellite systems can provide. But, adequate spectrum must be made available for both services if this desirable result is to be realized. Happily, there is a solution that can make it happen. We urge the Commission to modify its band segmentation plan as we have proposed.

## SUMMARY

NASA's charter includes the development of high-risk, innovative technology for the benefit of U.S. industry and the American public. We have worked in cooperation with the Commission since the 1960s to accomplish our objectives and to assist the Commission in carrying out its functions with respect to space systems. It is in this context that we comment on the instant proceeding.

We urge the Commission to modify its band segmentation plan by deleting LMDS in the 27.5-28.35 GHz band and by designating this spectrum instead for the FSS. We recommend that LMDS be retained in the 29.1-29.25 GHz band where sharing between the LMDS and MSS feeder links has been shown to be feasible. This 150 MHz wide band would enable LMDS to immediately implement systems competitive with today's cable systems if industry were to adopt use of digital modulation for LMDS. Use of modulation types other than digital would not take advantage of modern technology and would result in gross inefficiency in use of scarce spectrum resources.

We propose that the principal accommodation of LMDS be in the 40.5 - 42.5 GHz band where adequate spectrum is available for this new service to compete with cable operators, DBS operators, and others who will field expanded capability systems for multichannel video programming over the coming decade. We have performed a detailed analysis of the implementation of LMDS at 41 GHz and conclude that LMDS is as viable at this frequency as it is at 28 GHz. The bandwidth available in the 40.5-42.5 GHz band, coupled with the use of digital technology, is ideal for this purpose. It also offers ample opportunity for implementation of LMDS systems for educational uses.

from anywhere in the world, revolutionized international telephony, and produced dramatic decreases in the cost of overseas telephone calls.

NASA continues to develop high-risk, innovative technology for the benefit of U.S. industry and the American public. The latest communications satellite to be developed by NASA is the Advanced Communications Technology Satellite ("ACTS"), currently operating in the 20/30 GHz bands ("Ka-band") allocated world-wide to the Fixed-Satellite Service ("FSS") and designated in the United States for non-government use[1]. ACTS has been designed to pioneer these bands for subsequent use by the American communications industry. Thus, ACTS directly benefits the constituency of the FCC: American industry and the American public.

It is in this context that we comment on the instant proceeding. We were an active participant in the Commission's Negotiated Rulemaking Committee and we continue to be concerned that the reallocation proposed in the instant proceeding could preempt FSS use of 34%[2] of the Ka-band, restrict the use to which another 16% can be put, deprive the U. S. satellite industry of the spectrum needed to introduce the innovative new services that can be provided only at $K_a$-band frequencies and stunt the growth potential of the U. S. satellite industry.
We recommend careful consideration of all issues discussed below before allocations and rules are adopted that might radically alter the potential for delivery of communications services via satellite.

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1 Specifically, ACTS uplinks operate on 29.242 GHz (+/- 20.5 MHz), 29.263 GHz (+/- 82.5 MHz), and 29.298 GHz (+/- 20.5 MHz).

2 In the Commission's band segmentation plan, the FSS would be relegated to secondary status in 27.5 - 28.35 GHz representing 34% of the 2500 MHz total between 27.5 and 30.0 GHz. In addition, FSS use of 29.1 to 29.25 GHz, another 16% of the total band, would be limited to MSS feeder links.

## II. INTRODUCTION OF LMDS INTO THE 27.5-29.25 GHz BAND IS INCONSISTENT WITH GLOBAL USE OF FSS ALLOCATIONS

The fixed-satellite service is allocated uniformly over all three ITU regions in the frequency range from 27.5 to 30 GHz. This uniformity benefits U. S. satellite operators and manufacturers. It creates easier market entry in other countries and provides benefits in the form of lower costs to the American public that derive from the economies of scale. The potential to produce products at lower unit costs also benefits the competitiveness of American industry in international markets. Uniform allocations already exist throughout the world for the fixed-satellite service in the 27.5 -30.0 GHz band. This situation should not be allowed to change through adoption of alternative allocations in the United States.

Without a worldwide allocation, global Non-Geostationary Fixed Satellite Service (NGSO/FSS), global fixed-satellite and global mobile-satellite systems will be severely handicapped by a need to restrict the bandwidth used in the United States compared to that available in the rest of the world. This result would be contrary to the current efforts to simplify the Radio Regulations and to consider block allocations of spectrum.

We note that comments submitted to the Commission in response to its NPRM on use of radio frequencies above 40 GHz[3] also stressed the benefits that common worldwide allocations can produce. For example, stalwarts of American industry had this to say about the need for uniform worldwide frequency allocations:

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3 ET Docket No. 94-124, released November 8, 1994.

AT&T stated:

> In addition to opening up the millimeter wave spectrum to commercial use, the Commission should do everything it can to achieve similar allocations of that spectrum internationally[4]

General Motors argued for a common band for vehicular radars in the United States and Europe for the same reasons as given above[5].

Hewlett-Packard had this to say:

> Also, it should be pointed out, international coordination of regulatory efforts is mandatory from the point of view of American companies that wish to produce products for sale abroad. We hope that the proposals synthesized during the comment period will be given a thorough review for international compatibility, so that our radio regulations do not become de facto trade barriers.[6]

Rockwell International Corporation and the Telecommunications Industry Association (TIA) and others submitted similar comments.

It must be clear to the Commission that uniformity of allocations throughout the world is an important consideration as it prepares to adopt domestic allocations for the 27.5-30 GHz bands. The proposals advanced in the instant NPRM fail to meet this criterion.

We call to the Commission's attention that its proposals for the 27.5-30 GHz bands would create an imbalance between the amount of bandwidth allocated to the fixed-satellite service in the earth-to-space direction and the space-to-earth

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4 See AT&T comments to ET Docket No. 94-124 at p.5.

5 Comments of General Motors to ET Docket No. 94-124 at 22. Vehicular radars are not proposed for the 27.5 - 30 GHz bands.

6 See Hewlett- Packard comments to ET Docket No. 94-124 at 2.

**direction. As a result, the bandwidth proposed for the FSS is already insufficient to accommodate applications currently before the Commission[7]**

**The Commission's proposals set the stage for a future quest for additional FSS uplink spectrum to meet the needs of the satellite service. Surely, the Commission must remember the problems encountered at the 1992 World Administrative Radio Conference to meet the need for additional FSS uplink spectrum to balance the earth-to-space bandwidth with that in the space-to-earth direction. How much simpler it would be to preserve the present balance at $K_a$-band than to find additional spectrum at a later date!**

## III. LIMITING FSS $K_a$-BAND SPECTRUM WILL CONSTRAIN DEVELOPMENT OF THE FSS AND HURT U. S. SATELLITE MANUFACTURERS AND WILL NOT ACCOMMODATE PROJECTED REQUIREMENTS

**The 2.5 GHz bandwidth between 27.5 and 30 GHz offers the opportunity to develop new FSS applications that are not possible at C- and $K_u$- frequency bands. We concur with the Commission's opinion that 500 MHz represents the minimum bandwidth that is feasible for a viable FSS system at $K_a$-band. But, while this amount of spectrum might be adequate for certain services, it is woefully inadequate for wideband applications like Broadband-ISDN (B-ISDN) and supercomputer networks[8].**

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7 Loral Aerospace Holdings has requested a bandwidth of 1250 MHz for $K_a$-band up-links, PanAMSat has requested 2500 MHz and Teledesic Corporation has requested 1300 MHz.

8 In support of the federal High Performance Computing and Communications Program (HPCC), NASA, in cooperation with ARPA, has demonstrated high speed supercomputer and B-ISDN networking at rates up to 622 Mbps.

Commercially viable $K_a$-band satellite systems will make use of numerous, high-gain spot beams to enable the use of physically small earth terminal antennas, to achieve frequency reuse, and to obtain sufficient rain margins. The need for isolation between these beams will result in spectrum segmentation and significant reduction in the available spectrum per spot beam. For CONUS coverage using approximately 20 spot beams, NASA has analyzed a repetitive seven cell hexagonal arrangement of spot beams which provides the necessary isolation and can achieve substantial frequency reuse. Unfortunately, segmenting the spectrum seven times reduces the spectrum available for a specific spot beam. For example, with a 500 MHz allocation, the bandwidth available for a given spot beam would only be 72 MHz. Studies conducted for NASA by Space Systems/LORAL and COMSAT Laboratories[9], however, of satellite configurations capable of providing integrated voice, data and video services at 155 Mbs according to the B-ISDN concept concluded that an assignment of between 1200 MHz and 2500 MHz would be required. A 500 MHz block of spectrum could not support this application.

We note, as above, the plans of PanAmSat and Hughes to implement satellite systems that will operate internationally using 2500 MHz and 2000 MHz blocks of spectrum, respectively. These plans clearly show that 500 MHz blocks of spectrum are not optimum for FSS use at $K_a$-band.

When new spot beam satellite applications are considered along with the introduction of NGSO/FSS and mobile satellite feeder links it can be seen that the

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9 Price, K.; Kwan, R.; Chitre, D.; Henderson, T.; White, L.; Morgan, W.: "Applications of Satellite Technology to Broadband ISDN Networks", Space Systems/LORAL, NASA CR 189199, March 1992.

full 2500 MHz of spectrum currently allocated for the FSS at $K_a$-band will be needed in the very near future.

We would be remiss if we did not state to the Commission our view of the probable long-term consequences that segmentation to provide spectrum for LMDS entails. Limiting the primary spectrum available for satellite services in the 27.5-30 GHz band will impede the growth of the U. S. satellite industry, reduce competition among satellite providers and preclude future service opportunities, some of which are yet to be identified. Reaching a solution that satisfies the present needs of a small subset of the potential players in both LMDS and satellite industries will have lasting consequences on the future use of this valuable spectrum.

Internationally, the 27.5-30 GHz band will continue to be allocated on a primary basis for FSS earth-to-space links regardless of decisions made within the United States. As satellite applications are becoming increasingly global in nature, deviation from internationally recognized allocations by the U. S. will have adverse economic and competitive implications on our satellite industry as well as affecting our regulatory influence at future World Radiocommunication Conferences (WRC).

## IV. CO-FREQUENCY SHARING BETWEEN THE LMDS AND THE FSS IS NOT FEASIBLE

We concur with the Commission's tentative conclusion that co-frequency sharing between LMDS systems and either GSO/FSS or NGSO/FSS systems is not feasible at this time[10].

10 See NPRM at 43.

The subject of sharing between LMDS and FSS systems has been extensively studied since the Commission issued its first NPRM on LMDS in 1993. Even the group of experts who met under the auspices of the FCC's Negotiated Rulemaking Committee (NRMC) to examine the feasibility of co-frequency sharing between the proposed LMDS and the FSS was unable, despite the intense efforts of this group of experts, to devise a method that would make co-frequency sharing feasible. Subsequent studies by Bellcore and GeoWave have similarly been unsuccessful in finding techniques that would allow co-frequency sharing between ubiquitous systems in both LMDS and satellite services operating in the same geographical areas. An ex parte filing by the SBCA[11] of the MITRE report "Critique of the Bellcore Report" and the NASA ex parte filing[12,13] identified the deficiencies in the Bellcore report. The instant NPRM accurately summarizes[14] the reasons that the Bellcore report fell short of yielding a valid co-frequency sharing solution.

The conclusion that co-frequency sharing is not generally feasible is inescapable.

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11 See ex parte filing by the SBCA, June 6, 1995.

12 See June 7, 1995 ex parte filing by NASA, "NASA Comments on the Bellcore Study"

13 See July 7, 1995 ex parte filing by NASA, "Additional NASA Comments on the Bellcore Study"

14 See NPRM at 41.

## V. IT IS NOT NECESSARY TO LIMIT THE POTENTIAL OF EITHER LMDS OR FSS - ALTERNATIVE SPECTRUM IS AVAILABLE FOR LMDS

**We cannot agree with the Commission's tentative conclusion[15] that 41 GHz is not suitable for LMDS. We believe that the Commission has erred in its conclusion due to assigning unwarranted weight to the insupportable representations of 28 GHz LMDS proponents which claim that LMDS is not viable at 41 GHz. We are disappointed that the Commission has chosen to ignore the in-depth analysis that we provided to the Commission[16] and which shows that LMDS is, indeed, viable at 41 GHz. We note that information submitted by numerous parties in comments to the Commission's NPRM on use of frequencies above 40 GHz[17] support the viability of LMDS services at 41 GHz and this information has also been ignored. The Commission, in ET Docket No. 94-124 actually proposes to allocate the 40.5-42.5 GHz frequency band to the domestic fixed service, states its view that many of the uses of millimeter spectrum are likely to be technically and operationally similar to those contemplated for LMDS at 28 GHz and proposes to model its rules for 40.5-42.5 GHz after the rules and procedures proposed for LMDS[18]. It appears that this important information bearing favorably on use of 41 GHz for LMDS has inexplicably not been taken into account in the instant NPRM.**

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15 NPRM at 36.

16 See ex parte filing by NASA, "Suitability Analysis of Frequencies Above 40 GHz for LMDS and/or Commercial Satellite Communications Applications", July 7, 1995 filed under both CC Docket No. 92-297 and ET Docket No. 94-124.

17 Op cit.

18 Ibid. at 23.

The NASA study of the suitability of 41 GHz for LMDS examined the propagation environment, frequency dependent components, equipment availability and cost impact of providing LMDS services at 41 GHz vis-a-vis 28 GHz. It showed that by taking advantage of the higher gain that constant aperture antennas provide at the higher frequency, the same LMDS cell size can be maintained at either frequency. Although the rain attenuation for a given availability is greater at the higher frequency, an insignificant decrease in the availability from 99.9% to 99.86% results. We showed that an LMDS system could be fielded at 41 GHz with exactly the same number of cells as required at 28 GHz. This finding applies not only to rain climatic conditions that exist in New York but also to those that are found in the more rainy climates of the southeastern United States, including those found in Memphis, TN and Miami, FL. Other propagation effects such as gaseous attenuation, foliage attenuation and reflection/refraction are not appreciably different at 41 GHz from those at 28 GHz.

Only a small portion of the LMDS system elements that drive LMDS cost are frequency dependent. Those that are frequency dependent include the RF portion of the hub transmitter (upconverter and power amplifier), the hub and subscriber antennas, the RF portion of the subscriber receiver (low noise block downconverter), and for LMDS systems employing two-way communications, the RF portions of the subscriber transmitter and hub receiver. We showed that 41 GHz LMDS components suitable for implementation of LMDS are either available today or are technically feasible but have not yet been developed due solely to the lack of a market at 41 GHz. Surveys of manufacturers of these frequency sensitive components have revealed that performance equivalent to that available at 28 GHz can be obtained at a cost differential of approximately 20%. Given that these frequency dependent components constitute a small portion of the total cost of an LMDS system, the overall cost differential for LMDS deployment at 41 GHz would be minor, indeed, and would not be a factor in the economic viability of LMDS.

Development of 41 GHz traveling wave tubes (TWT) is judged to be the pacing component and these tubes could be available in 18-24 months from initiation of development with nearly simultaneous large volume production. We note that the current production capacity for 28 GHz TWTs is very low and that time would also be required to achieve the high volume production presumably needed for national deployment of LMDS at 28 GHz. We believe that the time to achieve volume production of TWTs at either 28 GHz or at 41 GHz will be substantially the same.

We note that the Commission recognizes that it will take time to produce the amount of hub and subscriber equipment needed for LMDS deployment[19] and has relaxed its build-out requirement. The Commission proposes to require that only one-third of the population in the geographical area of an LMDS service provider would have to have service within 5 years from license grant and only two-thirds of the population would have to be served within 10 years from license grant[20]. We believe that the reality implied by these lengthy build-out requirements moots arguments that implementation of LMDS at 41 GHz would be materially delayed compared to implementation at 28 GHz.

Additional evidence of the suitability of the 40.5-42.5 GHz band for near term implementation of LMDS is available to the Commission in the advice received in response to its NPRM on allocation and use of millimeter wave frequencies above

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19 NPRM at 114.

20 NPRM at 117.

40 GHz[21]. A vast majority of responders offered evidence that the technology needed to exploit frequencies above 40 GHz is available today and expressed the opinion that the Commission's proposed rules, if implemented, will spur rapid development of even more advanced technology in the near future. There was general agreement that the 40.5-42.5 GHz band should be allocated for licensed service and that rules suitable for LMDS in the 27.5-29.5 GHz band are appropriate in this band. The comments submitted by many of the most elite telecommunications and technology development companies in the country confirm that technology is readily available to develop LMDS in the 40.5-42.5 GHz frequency band.

We note also that the Commission received an independent assessment of the viability of LMDS at 41 GHz in a letter from the Massachusetts Institute of Technology Lincoln Laboratory that was filed in Docket No. 94-124[22]. In their letter, they have told the Commission that the technology exists to support component production at 41 GHz and that suppliers could readily supply components at reasonable cost. They go on to refute the statements of CellularVision regarding propagation at 41 GHz as well as component performance and cost that CellularVision claims would cause LMDS to not be viable at 41 GHz[23].

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21 ET Docket No. 94-124, released November 8, 1994.

22 MIT Lincoln Laboratory letter of 24 February 1995 filed under Docket No. 94-124.

23 See CellularVision comments filed under ET Docket No. 94-124 at, for example, 3B where it is claimed that there would be an astronomical cost penalty by a factor of 30-40 associated with implementation of LMDS at 40 GHz and at 3A where it is claimed that rainfall attenuation at 40 GHz will be so severe that it will jeopardize the viability of an LMDS system. See also, "LMDS is Not Viable in the Frequency Bands Above 40 GHz", Appendix 2 to the CellularVision comments.

The MIT Lincoln Laboratory letter apparently was filed only under the ET Docket and not in the instant proceedings being considered under CC Docket No. 92-297 and thus overlooked when the Commission formulated its band segmentation plan for the 27.5-30 GHz bands. We can not conceive of any other explanation for the Commission's apparent failure to take this information into account.

Perhaps, too, NASA's comments and reply comments which bear on the suitability of 41 GHz for implementation of LMDS which were filed in response to ET Docket No. 94-124 have not come to the Commission's attention in the instant proceeding. We attach these documents as Appendix 1 and Appendix 2 respectively to insure that the Commission has the complete information that it needs to make informed decisions on use of 27.5-30 GHz.

Finally, we draw the Commission's attention to NASA's ex parte submission "Suitability Analysis of Frequencies above 40 GHz for LMDS and/or Commercial Satellite Communications Applications"[24]

We urge the Commission to give serious consideration to the substantial record that supports the viability of LMDS at 41 GHz.

## VI. 40 GHz SPECTRUM IS NOT SUITABLE FOR THE FSS

NASA concurs with the Commission's conclusion that the 40.5-42.5 GHz band is not suitable for the satellite systems as proposed in this docket. We submit, however, that the reasons for this conclusion are more fundamental than the (valid) concern by satellite proponents that technologies have not been as fully developed and tested at 40 GHz as they have been at 28 GHz.

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24 Op cit.

There is an essential difference between LMDS systems and FSS systems that results in 41 GHz being suitable for LMDS but not, conversely, for commercial FSS. LMDS systems, by their terrestrial nature, can compensate for differences in rain attenuation across different rain zones by varying their cell sizes and thereby varying the path length through the rain. This is precisely what is proposed by CellularVision, for example, at 28 GHz[25]. As a result, the total attenuation at the edge of an LMDS cell is held constant across all rain zones. The same requirement can be met for the same size cells at 41 GHz as at 28 GHz. The higher attenuation at 41 GHz can be compensated through the increase in antenna gain as a function of frequency combined with a slight decrease (0.04%) in availability.

Satellites, on the other hand, whether in LEO, MEO or GEO, must traverse the same path length through the atmosphere at a given elevation angle for all rain zones. There is no means of reducing the path length except by raising the minimum elevation angle which limits the usable service arc. The increase in attenuation in rain zones with higher rain rates must therefore be compensated for by either increased transmitter power or larger antennas. The magnitude of change between rain zones D2 and E for 47.2-50.2 GHz (the lowest band allocated to the FSS above 40 GHz with sufficient bandwidth to replace the allocation at 27.5-30 GHz) is in excess of 5 orders of magnitude. The attenuation at 30° elevation angles for 99.9% availability is 39.99 dB in rain zone D2 versus 96.28 dB in rain zone E. The hardware penalty to the satellite system design is extreme - 100,000 times as much power would be required. Thus, the 47.5-50.2 GHz band is

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25 See Document NRMC/60 Chart "CellularVision - The 'rain issue'".

rendered unusable for commercial satellite communications services, given today's or currently foreseeable satellite technologies[26].

## VII. DIGITAL TECHNOLOGY IS AVAILABLE FOR INDUSTRY USE IN IMPLEMENTING LMDS SYSTEMS

The Commission seeks comments on when digital LMDS technology will be available in this country and the extent to which digital technology will expand the capacity of LMDS systems.

Digital technology for implementation of LMDS is available in this country today for industry use in LMDS systems. Any other form of modulation would cause a gross waste of valuable spectrum and would be inconsistent with the Commission's desire to insure efficient use of this scarce resource.

There is no question that advanced digital video compression combined with spectrally efficient modulation techniques can use LMDS spectrum much more efficiently than the analog FM technique which some, CellularVision for example, are proposing for video programming. CellularVision plans to transmit 50 20 MHz FM video channels in 1000 MHz of spectrum. This spectrum requirement can be significantly reduced using digital technology. Recent developments such as DBS, digital cable (General Instrument and others), and digital terrestrial HDTV (FCC "Grand Alliance"), make it clear that the future of television will be digital. Techniques being developed for these video delivery media can be readily applied to LMDS.

Consider the use of digital technology by DirecTV and USSB pay-TV DBS services now in operation. To compete with cable requires that the limited

26 For more detail, see NASA ex parte submission of July 7, 1995.

bandwidth and power resources on a satellite be used as efficiently as possible. Each of the three DBS satellites has 16 24 MHz transponders. Using MPEG2 video compression (now an international standard) and statistical multiplexing to dynamically share the 24 MHz transponder bandwidth, each transponder can accommodate 4 to 8 high quality video channels. (The actual number depends on the scene content and type of the programs sharing the same transponder as well as whether the satellite is operating in low power or high power mode.) After forward error correction (FEC) and QPSK modulation, the overall channel data rate per transponder is 40 Mbps resulting in an overall bandwidth efficiency of 1.7 bps/Hz. Using this digital compression/modulation approach for LMDS would accommodate 50 video channels within a bandwidth of 150 to 300 MHz with a spectrum efficiency in the range of about 6 to 3 times that of the system planned by CellularVision[27].

Terrestrial systems can utilize even more spectrum efficient modulation techniques than space systems since their transmitters are not power limited as are transmitters on satellites and they are not located 22,000 miles away from their audience as are transmitters on GEO satellites. Standards for advanced TV (ATV) for terrestrial broadcasting in the VHF/UHF bands are converging toward a fully digital implementation. In the U.S., the "Grand Alliance" (consisting of AT&T, General Instruments, MIT, Philips, Thomson Electronics, and Zenith Electronics) has been working towards an ATV transmission standard. The main challenge has been to squeeze an 18-20 Mbps compressed high definition video signal into a 6 MHz channel. A fully digital method based on the MPEG2 compression standard, Reed-Solomon/Trellis Coding, and high order QAM modulation is being developed. (Unlike power-limited satellite systems, terrestrial systems can

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27 Assumes an average compressed video data rate of 10 Mbps.

operate their power amplifiers in a "backed-off" linear mode, thereby allowing highly spectrally efficient non-constant envelope modulation schemes such as 64-QAM.) This approach will result in the needed bandwidth efficiency of about 4 bps/Hz. Assuming an average data rate of 10 Mbps for a compressed NTSC video channel, this compression/coding/modulation approach will allow use of 2.5 MHz channel bandwidths for NTSC video and will result in a capacity of 400 channels in a 1000 MHz block of spectrum - 8 times the CellularVision capacity using analog FM.

Wired cable operators and wireless cable operators (Multichannel Multipoint Distribution Service or MMDS) are also planning to use these spectrum efficient modulation and coding techniques to expand the number of channels in their systems. We note that the Wireless Cable Digital Alliance has announced that it will conduct a commercial trial of digital technology delivering 150 - 300 channels of programming through wireless cable systems that are currently limited to 33 channels[28]. It is stated that the trial is expected to begin in the fourth quarter of 1995, pending FCC approval. Several companies have implemented or are now implementing equipment using joint MPEG2-QAM video transmission methods. Examples include Scientific Atlanta's Powervu TV, Compression Labs Inc.'s Magnitude MPEG2, and General Instrument's Digicipher II digital TV system. The GI system complies with the recently adopted ITU 64-QAM FEC transmission standard for North America. This standard features concatenated Reed-Solomon outer coding and advanced trellis inner coding to allow the same FEC technology to be used for both wired (cable/teleco) and wireless (MMDS) applications. GI's Digicipher II system, which uses MPEG2 compression in conjunction with FEC and 64-QAM modulation accommodates transmission of 30 Mbps of digital data in

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28 Satellite Journal International, August, 1995.

a 6 MHz bandwidth - a bandwidth efficiency of 5 bps/Hz. In addition, GI is now working with other leading companies such as Broadcom Corp. to define extensions to the ITU standard for operation using 256-QAM. This next generation Digicipher system would enable 40 Mbps data rates in a 6 MHz bandwidth - an efficiency of 6.7 bps/Hz. Zenith Electronics Corp.'s 16-VSB (16 level - vestigial sideband) modulation technology is also a very bandwidth efficient digital video transmission approach. Depending on the amount of compression used, the system will be able to transmit as many as 23 movie channels, 9 live video programs, or 2 HDTV signals in each 6 MHz cable channel. Field tests have demonstrated that the 16-VSB system can transmit and receive 43 Mbps of data in a single 6 MHz channel - an efficiency of 7 bps/Hz. Again assuming an average compressed data rate of 10 Mbps for a NTSC video channel, this bandwidth efficiency would yield a capacity of 700 channels in a 1000 MHz of spectrum.

The preceding discussion leads to a conclusion that a digital implementation of LMDS has the potential to support anywhere from roughly 200 to 700 video channels in 1000 MHz of spectrum depending on the specific coding and RF modulation that is used. Higher order QAM modulation or VSB modulation gives higher capacity than the lower order PSK modulation typically required in satellite systems. Given this increased capacity with digital technology, a competitively viable LMDS system providing as many as 105 video channels in 150 MHz[29] of spectrum certainly is feasible.

[29] A capacity of 700 video channels in a bandwidth of 1000 MHz corresponds to a bandwidth of 1.43 MHz per channel. A bandwidth of 150 MHz would accommodate 105 video channels.

## VIII. ADOPTION OF APPROPRIATE TECHNICAL RULES WILL CONSERVE VALUABLE SPECTRUM AND FACILITATE IMPLEMENTATION OF NEW SERVICES

The Commission has requested comments regarding the appropriateness of its proposals for technical rules to be applied to the LMDS and satellite services. We offer our comments in the sections that follow.

### 1. Polarization

Restricting adjacent LMDS systems to use orthogonal polarizations (either orthogonal linear polarizations or orthogonal circular polarizations) along their common borders should improve the isolation between them. However, as noted during the NRMC proceedings, polarization discrimination is not a significant mitigating factor when considering interference from FSS uplink earth stations into LMDS subscriber receivers. The reason is that interference power received by the LMDS receivers will generally be due to power radiated from the sidelobes of the earth station antenna and not from its main beam. The narrow main beam of the antenna will be pointed at the GEO or LEO satellite it is communicating with - typically 30° or 40° above the horizon. Even though an antenna may have a given polarization in its main beam, the polarization in the sidelobes of the pattern may be completely different. In general, off the main beam, the field will be randomly elliptically polarized with random axial ratio and major axis tilt angle. Recall that linear and circular polarizations are just special cases of elliptical polarization. For linear polarization, the axial ratio is infinity. For circular polarization, the axial ratio is ±1 depending on whether the rotation is left hand or right hand. The amount of polarization discrimination that a particular LMDS receiver will have against interference from a particular FSS uplink antenna will depend on 4 factors: (1) the axial ratio of the interfering wave in the direction of the LMDS receiver; (2) the axial ratio of the LMDS receiving antenna in the direction of the interfering FSS antenna; (3) the major axis tilt angle of the interfering wave in the direction of the LMDS receiver; and (4) the major axis tilt angle of the receiving antenna polarization in the direction of the FSS antenna. If the axial ratios and tilt angles match, then there is perfect polarization matching and no discrimination at all. Note that to compute the discrimination requires knowledge of the complete 3-dimensional polarization patterns of both antennas. A further complication occurs within the near-field of either antenna, since there is now an additional E-field component. Lacking sufficient antenna pattern data, polarization discrimination was ignored in the NRMC calculations, although it may be argued that an average polarization mis-match providing 3 dB of discrimination could be assumed from a statistical viewpoint. This is equivalent to the polarization matching between a linearly polarized antenna and a circularly polarized wave (or vice versa).

### 2. Equivalent Isotropically Radiated Power (EIRP)

We have no quarrel with the EIRP limits proposed for LMDS systems. Indeed, there are benefits that accompany low values and from the degree of homogeneity among LMDS systems that would result. However, we must point out that low EIRP levels will not advance the stated goal of improving the chances of future co-frequency sharing agreements between LMDS and satellite licensees in the 27.5-28.35 GHz band. The predominant interference path is from satellite earth station transmitters into LMDS receivers. A low LMDS EIRP will make it more susceptible to interference. Conversely, a high EIRP would make the LMDS system less susceptible.

The interference path from LMDS to the FSS will, in general, be at moderate to high elevation angles where the LMDS antenna gain can be expected to be at its minimum value. The EIRP directed toward an FSS, in this case, will be only a function of the LMDS transmit power because the LMDS antenna gain will be a constant in the far sidelobe regions. A limit on maximum transmitter output power would serve to constrain the maximum interference produced by an LMDS station at large angles away from the mainbeam direction and would serve as a mitigating factor for this interference mechanism.

### 3. Spectral Efficiency

By the Nyquist bandwidth constraint, the theoretical minimum required bandwidth to transmit and receive $R_s$ symbols per second without intersymbol interference (ISI) for a double sideband signal is $B = (1+r) R_s$ where r is the filter roll-off factor to account for non-ideal rectangular filtering. Typically, r is 10%-25% so that the symbol rate-to-bandwidth ratio is 0.8 - 0.9 sps/Hz (symbols per second per Hz). The bandwidth efficiency in terms of bits per sec per Hz depends on how many bits each digital symbol represents which in turn depends on the modulation scheme. For an M-ary scheme, each symbol represents $k = \log_2(M)$ bits. Hence, 2-level schemes such as BPSK have a bandwidth efficiency of 0.8-0.9 bps/Hz, 4-level schemes such as QPSK are 1.6-1.8 bps/Hz[30], 8-level schemes are 2.4-2.7 bps/Hz, 32-level schemes are 4.0-4.5 bps/Hz, etc. The current standard of 1.0 bps/Hz is completely out of date for digital data transmission. As discussed previously, QPSK is a well established digital modulation technique, even for

30 The bandwidth efficiency of QPSK is often stated as 1 bps/Hz. This arises from the QPSK power spectral density and use of the null-to-null bandwidth. Obviously, the bandwidth efficiency will depend on the definition of bandwidth that one is using. The bandwidth definition used here is the Nyquist bandwidth needed to avoid inter-symbol interference.

space systems, and higher order M-ary PSK and QAM schemes are available for digitally modulated terrestrial systems. As noted above, overall spectral efficiencies for current and near-term digital video communication systems range from 1.7 bps/Hz (DBS) to about 7 bps/Hz (256-QAM).

We recommend that the requirement for spectral efficiency for LMDS be set no lower than the 4 bps/Hz being achieved in the ATV arena. This efficiency is consistent with 32-level or higher QAM modulation schemes and should pose no problem to equipment manufacturers.

4. FSS Frequency Reuse

The NPRM proposes at paragraph 126 to require full frequency reuse for the GSO/FSS systems that will use the 27.5-30 GHz band. This rule is currently contained in Part 25 of the Commission's rules and is an appropriate requirement at C - band and $K_u$ - band where it can double the effective use of the spectrum through cross polarization. However, a requirement that both polarizations be used in the same spot beam of a GSO/FSS satellite is not appropriate. Spot beam satellites achieve frequency reuse in an entirely different manner than satellites that cover all of CONUS in a single beam. Spot beam satellites reuse the same frequency in spatially independent beams. Polarization discrimination is used to isolate one beam from another. Spot beam satellites can make very efficient use of the spectrum by multiple reuse of frequencies in separate beams but can not reuse the same spectrum within a single spot beam. Perhaps an appropriate alternative rule would be to require "X" times frequency reuse within the service area of the FSS system where "X" remains to be specified.